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ALIGNING IN FIVE DEGREES OF FREEDOM A MULTICHANNEL LASER PRINTHEAD FOR TRANSFERRING OLED MATEIRAL

FIELD OF THE INVENTION

The present invention relates to organic light-emitting display devices and, in particular, to methods of aligning, maintaining, and calibrating a multichannel laser printhead used in manufacturing organic light-emitting diodes (OLEDs).

BACKGROUND OF THE INVENTION

OLEDs are useful in a variety of applications as discrete light-emitting devices, or as the active element of light-emitting arrays or displays, such as flat-panel displays in watches, telephones, digital cameras, laptop computers, pagers, cellular phones, calculators, and the like.

Conventional OLED display structures are built on glass substrates in a manner such that a two-dimensional OLED array for image manifestation is formed. Each OLED in the array generally includes overlying layers, starting with a light-transmissive first electrode formed on the substrate, an organic electroluminescent (EL) emission medium deposited over the first electrode, and a metallic electrode on top of the organic electroluminescent medium. When an electrical potential is placed across the electrodes, holes and electrons are injected into the organic zones from the anode and cathode, respectively. Light emission results from hole-electron recombination within the device.

One technical challenge relating to OLED technology is fabrication. Well known shadow mask-based vacuum deposition technology, using conventional vacuum chambers, is often used for manufacturing OLEDs. However, shadow mask-based vacuum deposition technology is limited in the precision of the deposition geometry. A laser thermal transfer (LTT) process is an example of an emerging thermal transfer deposition technology for manufacturing OLEDs with potential advantages over conventional deposition processes. LTT is a process that uses heat to transfer organic materials from a donor to a substrate. More specifically, a laser beam generates heat by impinging upon the donor, thereby vaporizing the material and depositing it upon the target substrate in a predefined pattern. Several technical challenges exist for manufacturing OLEDs

using the LTT process, such as initial setup, maintenance, and calibration of a printhead, especially a multichannel laser printhead.

For example, U.S. Patent 6,362,847 describes how the write lines of a color laser printer are maintained substantially equal throughout the printer's operation by an electronic control arrangement. At the factory, the write lines on all photoconductors of the color laser printer are calibrated to be substantially equal, and the ratio of each write line to a measuring line for each photoconductor is ascertained. During operation of the printer, the length of each of the measuring lines is periodically determined through counting the number of PELslice clock timing pulses produced from a PELslice clock operating at a fixed frequency determined during factory calibration. While U.S. Patent 6,362,847 describes a suitable method of calibrating a laser printer, it does not provide a process for initial setup, maintenance, and calibration of a multichannel laser printhead in an LTT process for manufacturing OLED display devices.

It is therefore an object of the invention to provide a system for and method of aligning, calibrating, and maintaining a multichannel laser printhead in an LTT process for manufacturing OLED display devices, thereby minimizing errors in processing.

It is another object of the invention to measure the laser light beams that can affect the uniformity of printing in an LTT process for manufacturing OLED display devices so that a correction or channel-balancing algorithm might be applied (not included).

It is yet another object of the invention to provide a simple detection method of evaluating or verifying the operating condition of a multichannel laser printhead in an LTT process for manufacturing OLED display devices.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to more effectively use a multichannel laser printhead for transferring organic materials from a donor to a substrate in making an OLED device.

This object is achieved by a method of aligning in five degrees of freedom a multichannel laser printhead to be used in thermal transfer of material from a donor to a substrate, comprising:

a) providing a detection system forming a narrow aperture positioned in a plane parallel to the material transfer plane in the donor, a photodetector responsive to laser light passing through the narrow aperture to produce a signal, and further providing a controller adapted to produce a first and second series of laser irradiance profiles;

b) positioning the multichannel laser printhead in x and y directions parallel to the material transfer plane;

c) using a motion control system to sequentially position and scan in a direction perpendicular to the narrow aperture for at least one channel of the multichannel laser printhead and then for at least one other channel of the multichannel laser printhead relative to the aperture from an out-of-focus position through an above focus position so that the controller receives the signals from the photodetector and the motion control system to produce the first and second series of laser irradiance profiles;

d) using the first and second series of laser irradiance profiles to determine correction values needed for roll and yaw of the multichannel laser printhead and distance of the multichannel laser printhead from the material transfer plane;

e) aligning the multichannel laser printhead in accordance with the correction values whereby the multichannel laser printhead is aligned without performing a thermal transfer operation; and

f) establishing the x and y coordinates of each channel of the multichannel laser printhead with respect to x and y coordinates of the motion control system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a high-level block diagram of a laser thermal (LT) printer system;

FIGS. 1A and 1B illustrate a side view and top view, respectively, of the laser thermal (LT) printer system of FIG. 1 for use in an OLED fabrication process;

FIG. 2 illustrates an exploded view of a first portion of a detection system of the multichannel laser printer system in accordance with the invention;

FIG. 3 illustrates a series of plots that are representative of a typical laser irradiance profiles vs. Y position of the multichannel laser printhead as measured by a Y-photodetector in accordance with the invention;

FIG. 4 illustrates an exploded view of a second portion of the detection system of the multichannel laser printer system in accordance with the invention;

FIG. 5 illustrates two plots that are representative of typical laser irradiance profiles of all channels of an multichannel laser printhead as a function of the irradiance detected by an X-photodetector vs. the X position of the multichannel laser printhead;

FIG. 6 shows a flow diagram of a method of replacing a printhead within an LTT process for OLED fabrication in accordance with the invention;

FIG. 7 shows a flow diagram of a method of initially setting up a printhead within an LTT process for OLED fabrication in accordance with the invention; and

FIG. 8 shows a flow diagram of a method of measuring channel irradiance profiles and total power of a printhead within an LTT process for OLED fabrication in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a system for and method of alignment, maintenance, and calibration of a multichannel laser printhead in a laser thermal (LT) printing system. The multichannel laser printhead would be one that can selectively produce laser beam outputs from different positions. An example of such a printhead would be one with a single linear laser bar source illuminating a spatial modulator, an example of which is set forth in U.S. Patent 6,582,875.

The multichannel laser printer system of the present invention includes a motion control system upon which is mounted a LT station and a

detection system. The detection system is located in the same plane, or with a small measured offset in Z, as a donor in a Z position correlating to best focus, thereby providing a reliable reference for use when the multichannel laser printhead of the LT printer system is replaced or calibrated, or when the health of the multichannel laser printhead is being verified. The best focus plane of the multichannel laser printhead is the plane whereby the irradiance (power/area) of the multichannel linear laser light beams are maximum. Any other plane, at a different Z value, is considered out of focus.

FIG. 1 illustrates a high-level block diagram of laser thermal (LT) printer system **100** for use in an OLED fabrication process. LT printer system **100** includes a vacuum chamber **122**, a controller **111**, a motion control system **110** upon which is mounted a laser thermal (LT) station **112**, and a detection system **114**. Laser light beams can be directed to either the vacuum chamber **122** or the detection system **114** depending upon the positional commands **113** sent to the motion control system **110**, and further depending upon the printhead control commands **115** sent by the controller **111** to the LT station **112.** In response to the receipt of laser light beams directed to the correct portion of detection system **114**, and upon commands from the controller **111**, the detection system **114** will return irradiance data **117** to the controller **111**. During the gathering of irradiance data **117,** the controller **111** also gathers positional data **119** from the motion control system **110**.

FIGS. 1A and 1B illustrate a more detailed side view and top view, respectively, of portions of laser thermal (LT) printer system **100** including the motion control system **110** upon which is mounted an LT station **112** and a detection system **114**.

LT station **112** further includes a multichannel laser printhead **116** that typically uses a semiconductor laser bar source with illumination optics, a spatial light modulator, and post modulator optics to provide linear laser light beam channels 1 through n, where n is, for example, 256. Multichannel laser printhead **116** allows for individual on/off control of each channel. Multichannel laser printhead **116** is, for example, similar to the multichannel laser printhead of U.S. Patent 6,169,565 B1 or EP 1 252 024. LT station **112** further includes motion

control system **110** is a conventional precision motion control system that provides multichannel laser printhead **116** with precision X, Y, Z, and theta-Z (Θ_Z) (rotation about the Z-axis or yaw), and theta-Y (Θ_Y)(rotation about the Y axis or roll), motion relative to a donor **120** mounted within a conventional vacuum chamber **122**. The conventions for motion in each axis for the embodiment are as follows: the X-axis is stepped during a slow scan; the Y-axis is quickly scanned; and the Z-axis is used to focus the laser light beams. During the installation of multichannel laser printhead **116**, there is another multichannel laser printhead angular adjustment theta-Y (Θ_Y) (rotation about the Y-axis or roll according the convention used here) to orient all the laser light beams to focus in the plane of donor **120**. Donor **120** consists of a support layer that is predominantly transparent to the printhead laser wavelength and an energy absorbing layer, atop which is deposited an organic transfer layer typically formed of electroluminescent organic material. Lastly, LT station **112** includes a window **124** mounted within a chamber wall **126** of vacuum chamber **122**.

Similarly, detection system **114** includes a window **128**, an X-slit aperture **130** having a slit **132**, a Y-slit aperture **134** having a slit **136**, an X-attenuator **135**, a Y-attenuator **137**, an X-photodetector **138**, and a Y-photodetector **140**, all of which are enclosed by an enclosure **142** that is mechanically attached to chamber wall **126** of vacuum chamber **122**. Window **128** is mounted within chamber wall **126** of vacuum chamber **122**. Window **128** is aligned with X-slit aperture **130** and Y-slit aperture **134**. X-slit aperture **130** is aligned with X-photodetector **138** and Y-slit aperture **134** is aligned with Y-photodetector **140**. The spacing between X-slit aperture **130** and X-photodetector **138** and the spacing between Y-slit aperture **134** and Y-photodetector **140** is fixed at an optically advantageous predetermined distance. Enclosure **142** serves to isolate detection system **114** from the vacuum environment of vacuum chamber **122**. It is alternatively possible to eliminate the use of window **128** for low numerical aperture (e.g., 0.06 NA) laser light beams, when no significant optical aberration is introduced by removal of the window.

A narrow aperture of uniform gap, sometimes referred to as a slit aperture, is shown as X-slit aperture **130** in FIG. 1B, and another is shown as

Y-slit aperture **134.** These are custom aperture devices that have narrow openings (i.e., slit **132** and slit **136**, respectively) through which light passes. Slit **132** and slit **136** are oriented orthogonal to one another, as shown in FIG. 1B. X-photodetector **138** and Y-photodetector **140** are conventional optical sensors, such as United Detector Technology PIN 6DI, for detecting the laser light wavelength band.

Window **124** is aligned with donor **120** such that the laser outputs of multichannel laser printhead **116** may enter vacuum chamber **122** via window **124** to impinge upon donor **120** during operation, with minimal distortion. Similarly, window **128** is aligned with X-slit aperture **130** and Y-slit aperture **134** such that the laser outputs of multichannel laser printhead **116** may enter enclosure **142** via window **128** to impinge upon X-photodetector **138** and Y-photodetector **140** during operation, with minimal distortion. Motion control system **110** allows for the X-Y motion of multichannel laser printhead **116** over the full range of the areas of windows **124** and **128**.

CCD camera **144** is a charge coupled device camera and is a well known position measurement device by those skilled in the art, for example, a CCD camera imaging system from Spiricon Inc. CCD camera **144** is used to establish the X-Y coordinates of each channel of multichannel laser printhead **116** with respect to the X and Y coordinates of motion control system **110**.

The operation of LT station **112** is as follows: multichannel laser printhead **116** generates one or more selected laser light beams **118** based upon a predefined pattern. Laser light beams **118** then pass through window **124** of vacuum chamber **122** and impinge upon donor **120** in this predefined pattern. The majority of the laser energy is absorbed by a light-absorbing layer within donor **120** and is converted to heat. The conversion of the laser's energy to heat sublimates the organic material that forms the top layer of donor **120**, thereby vaporizing the organic material and forming an evaporant that is deposited in the desired subpixel pattern upon a substrate (not shown) for forming an OLED display device. The planar region defined by the light-absorbing layer within donor **120** and the top layer of the donor **120** is referred to as the material transfer plane.

X-slit aperture **130** and Y-slit aperture **134** of detection system **114** are set in the same plane as donor **120,** or parallel to the donor plane with an offset in Z, so that they are a reliable reference for use when multichannel laser printhead **116** is replaced or simply when the health of multichannel laser printhead **116** is being checked. The setup and operation of detection system **114** is described in reference to FIGS. 2 through 8.

FIG. 2 illustrates an exploded view **200** that is representative of a first portion of detection system **114**. More specifically, exploded view **200** demonstrates the operation of multichannel laser printhead **116** in conjunction with Y-slit aperture **134**, set at a fixed distance from Y-photodetector **140**. FIG. 2 illustrates three positions for multichannel laser printhead **116**. The lowest Z height position, the position at which the multichannel laser printhead **116** is removed and replaced, is designated as the –D position. The Z height of replacement multichannel laser printhead **116** that produces peak laser irradiance is designated as the N position. The highest position of Z height of replacement multichannel laser printhead **116** is designated as the +D position. Additionally, FIG. 2 illustrates laser light beams **118** emitting from multichannel laser printhead **116**, passing through window **124**, and subsequently passing through slit **136** of Y-slit aperture **134**, where a portion of the light subsequently impinges upon Y-photodetector **140**. Furthermore, Y-attenuator **137** for attenuating the light is located between Y-slit aperture **134** and Y-photodetector **140**. Y-attenuator **137** is a well known device that reduces the power of the optical signal by inducing loss. The width of slit **136** is set to, for example, the equivalent of the full-width-half-maximum ($FWHM_y$) of laser light beams **118**, for example, 9 microns. As multichannel laser printhead **116** is scanned along the Y-axis, laser light beams **118** impinge upon Y-photodetector **140**. A laser irradiance profile, such as that shown in FIG. 3, is measured via Y-photodetector **140** multichannel laser. This laser irradiance profile relates the irradiance data **117** to the positional data **119**, which indicates the location in Y of the printhead as gathered during the scanning process from the motion control system **110**. The laser irradiance profile varies depending upon the Z height of multichannel laser printhead **116** relative to Y-slit

aperture **134**, in a fashion consistent with being out of focus in either the –D or +D position, or in focus at the N position.

FIG. 3 illustrates a plot **300** that is representative of three typical laser irradiance profiles as measured by Y-photodetector **140**. The laser irradiance profile varies depending upon the Z height of multichannel laser printhead **116** relative to Y-slit aperture **134**. For example, a curve **310**, a curve **320**, and a curve **330** are sample laser irradiance profiles associated with various Z height settings of multichannel laser printhead **116** relative to Y-slit aperture **134**. Curve **330** is representative of the best focus Z height setting of multichannel laser printhead **116** relative to Y-slit aperture **134**, in which a maximum value of irradiance is achieved. Further details of how these irradiance profiles are used within LT printer system **100** are described with reference to FIGS. 6, 7, and 8.

FIG. 4 illustrates an exploded view **400** that is representative of a second portion of detection system **114**. More specifically, exploded view **400** demonstrates the operation of multichannel laser printhead **116** in conjunction with X-slit aperture **130** that is set at a fixed distance from X-photodetector **138**. FIG. 4 illustrates laser light beams **118** emitting from multichannel laser printhead **116**, passing through window **124**, and subsequently arriving at the plane of slit **132** of X-slit aperture **130**, where a portion of the light subsequently impinges upon X-photodetector **138**. Furthermore, X-attenuator **135** for attenuating the light is located between X-slit aperture **130** and X-photodetector **138**. X-attenuator **135** is a well known device that reduces the power of the optical signal by inducing loss. The width of slit **132** is set to, for example, the equivalent of the FWHM of a single laser light beam channel in the X dimension, for example, 20 microns. As multichannel laser printhead **116** is scanned along the X-axis, all laser light beams **118** associated with channels 1 to n sequentially impinge upon X-photodetector **138**. An irradiance profile for laser light beams **118**, such as those profiles shown in FIG. 5, is measured via X-photodetector **138** multichannel laser. This laser irradiance profile relates the irradiance data **117** to the positional data **119** in X of the printhead as gathered during the scanning process from the motion control system **110**. The laser light beam irradiance profile may vary due to nonuniformities in the laser light source and the optical elements in multichannel

laser printhead **116**. X-slit aperture **130** should be at the best focus, as defined for Y-slit aperture **134** in the previous paragraph. The assembly of X-slit aperture **130** with X-photodetector **138** is mechanically coupled in the same plane as the assembly of Y-slit aperture **134** with Y-photodetector **140**, so that both are in the best focus plane.

FIG. 5 illustrates a plot **500** that is representative of a measurement of two typical laser light beam channel irradiance profiles of all channels of multichannel laser printhead **116** as a function of radiance detected by X-photodetector **138** vs. the X position of multichannel laser printhead **116**. An ON curve **510** is a plot representative of all channels 1 to n turned on as multichannel laser printhead **116** is scanned along the X-axis and a maximum value of irradiance is achieved, assuming a best focus Z height setting of multichannel laser printhead **116** relative to X-slit aperture **130**. An OFF curve **520** is a plot representative of all channels 1 to n turned off as multichannel laser printhead **116** is scanned along the X-axis and a minimum value of irradiance data **117** is achieved, assuming a best focus Z height setting of multichannel laser printhead **116** relative to X-slit aperture **130**. Further details of how the measurements represented by ON curve **510** and OFF curve **520** are used within LT printer system **100** are described in reference to FIGS. 6 and 8.

FIG. 6 shows a flow diagram of a method **600** of replacing multichannel laser printhead **116** within an LTT process for OLED fabrication in accordance with the invention. LT printer system **100** as described in FIGS. 1-5 is referenced throughout the steps of method **600**. Method **600** includes the following steps:

Step **610**: Installing printhead

In this step, multichannel laser printhead **116** is removed and a replacement multichannel laser printhead **116** is installed. Method **600** proceeds to step **612**.

Step **612**: Activating first end of printhead

In this step, at least one channel of the multichannel laser printhead located at the first end of replacement multichannel laser printhead **116** are activated. Method **600** proceeds to step **614**.

Step **614**: Lowering Z height of replacement printhead to –D position

In this step, the Z height of replacement multichannel laser printhead **116** is lowered to a –D position, also known as an out-of-focus position, using a micrometer Z position translator, where –D is, for example, -250 microns from N, where N has been determined previously by an additional process Method **600** proceeds to step **616**.

Step **616**: Positioning multichannel laser printhead to Y-slit detector

In this step, replacement multichannel laser printhead **116** is translated along the X-axis and Y-axis of LT printer system **100** using motion control system **110** such that the active channel(s) of replacement multichannel laser printhead **116** are located in alignment with Y-slit aperture **134**. Motion control system **110** records the X- and Y-coordinates of this position. Method **600** proceeds to step **618**.

Step **618**: Scanning multichannel laser printhead and measuring laser irradiance profile

In this step, at least one channel of the replacement multichannel laser printhead **116** are scanned across Y-slit aperture **134** along the Y-axis using motion control system **110**. The resulting laser light beams **118** pass through slit **136** of Y-slit aperture **134** and impinge upon Y-photodetector **140**. Method **600** proceeds to step **620**.

Step **620**: Storing irradiance profile measurement

In this step, Y-photodetector **140** detects the irradiance of laser light beams **118** and generates an output signal accordingly that is received and recorded by the controller **111** of LT printer system **100**. In addition, the motion control system **110** generates an output signal indicating the Y location of the printhead during scanning that is received and recorded by the controller **111** of the LT printer system **100**. Method **600** proceeds to step **622**.

Step **622**: Raising Z height of printhead

In this step, the Z height of replacement multichannel laser printhead **116** is raised by a predetermined increment ΔD using a micrometer Z position translator. ΔD is, for example, +25 microns. Method **600** proceeds to step **624**.

Step **624**: Scanning multichannel laser printhead and measuring irradiance profile

In this step, at least one channel of replacement multichannel laser printhead **116** are scanned across Y-slit aperture **134** along the Y-axis using motion control system **110**. The resulting laser light beams **118** pass through slit **136** of Y-slit aperture **134** and impinge upon Y-photodetector **140**. Method **600** proceeds to step **626**.

Step **626**: Storing irradiance profile measurement

In this step, Y-photodetector **140** detects the irradiance of laser light beams **118** and generates an output signal accordingly that is received and recorded by the controller **111** of LT printer system **100**. In addition, the motion control system **110** generates an output signal indicating the Y location of the printhead during scanning that is received and recorded by the controller **111** of the LT printer system **100**. Method **600** proceeds to step **628**.

Step **628**: Has +D position been reached?

In this decision step, it is determined whether the Z height of replacement multichannel laser printhead **116** is set at the +D position, also known as an above focus position. If yes, method **600** proceeds to step **630**. If no, method **600** returns to step **622**.

Step **630**: Storing Z height of multichannel laser printhead according to peak irradiance

In this step, the Z height of replacement multichannel laser printhead **116** that produces peak laser irradiance is determined and stored for one or more active channels of replacement multichannel laser printhead **116**, such as curve **330** of plot **300** of FIG. 3, as measured by the controller **111** of LT printer system **100**. Method **600** proceeds to step **632**.

Step **632**: Center channels of multichannel laser printhead scanned?

In this decision step, it is determined whether one or more active channels in the middle of replacement multichannel laser printhead **116** have been scanned across Y-slit aperture **134** along the Y-axis using motion control system **110**. If yes, method **600** proceeds to step **636**. If no, method **600** proceeds to step **634**.

Step **634**: Activating center channels of printhead

In this step, all channels of replacement multichannel laser printhead **116** are deactivated. Subsequently, one or more channels located in the middle of replacement multichannel laser printhead **116** are activated. Method **600** returns to step **614**.

Step **636**: Both ends of multichannel laser printhead scanned?

In this decision step, it is determined whether both ends of replacement multichannel laser printhead **116** have been scanned across Y-slit aperture **134** along the Y-axis using motion control system **110**. If yes, method **600** proceeds to step **640**. If no, method **600** proceeds to step **638**.

Step **638**: Activating second end of printhead

In this step, all channels of replacement multichannel laser printhead **116** are deactivated. Subsequently, one or more end channels located at the second end of replacement multichannel laser printhead **116** are activated. Method **600** returns to step **614**.

Step **640**: Determining Theta-Y, Theta-Z, and height Z of multichannel laser printhead

In this step, Theta-Y (Θ_Y), Theta-Z (Θ_Z), and height Z are calculated for multichannel laser printhead **116** using the Z height data determined in step **630**, and irradiance data measured in steps **618** and **624** from both end channel or channels of the printhead, and center channels if desired. Theta-Y (Θ_Y), Theta-Z (Θ_Z), and height Z of multichannel laser printhead **116** are determined to achieve best focus position N from channel 1 to channel n. The corresponding correction values or amplitudes of adjustment to the Theta-Y (Θ_Y), Theta-Z (Θ_Z), and height Z of multichannel laser printhead **116** are also determined. Method **600** proceeds to step **642**.

Step **642**: Adjusting and locking Theta-Y, Theta-Z, and height Z of multichannel laser printhead

In this step, multichannel laser printhead **116** is adjusted in three degrees of freedom based upon the correction values, if required, using Theta-Y (Θ_Y), Theta-Z (Θ_Z), and height Z calculated in step **640** to achieve best focus

position N from channel 1 to channel n at the material transfer plane, that can be offset in Z from the slit detector plane, and also that laser light beams **118** are orthogonal to the Y-axis. The adjustments of the printhead orientation, (Theta-Y (Θ_Y), Theta-Z (Θ_Z)), and Z height can be made manually or automatically using additional axes of control in the previously described motion control system **110**. The orientation and Z height of replacement multichannel laser printhead **116** are locked into place. Method **600** proceeds to step **644**.

Step **644**: Establishing X-Y coordinates of printhead

In this step, the first and last (n^{th}) channel, for example, of replacement multichannel laser printhead **116** are imaged with CCD camera **144** to establish the X-Y coordinates of each channel centroid with respect to the X and Y coordinates of motion control system **110**. This step provides the alignment in the final two degrees of freedom, X and Y, of the printhead relative to the motion control system **110**. Method **600** ends. Reviewing, the above method aligns a multichannel laser printhead in five degrees of freedom.

In an alternate embodiment of method **600**, a CCD camera with appropriate attenuator and image-processing software that determines peak light level could be used in lieu of Y-slit aperture **134** and Y-photodetector **140** to determine the laser light beam channel peak irradiance for Z height in steps **616** through **626**. The laser light beam channel X, Y centroid location is a determined with appropriate CCD image-processing software using for example, a CCD camera imaging system from Spiricon Inc. Good uniform CCD pixel response and camera calibration are important to the successful implementation of this alternative measurement method.

In summary, method **600** is a method of replacing multichannel laser printhead **116** within an LTT process for OLED fabrication in accordance with the invention. This is accomplished by locating Y-slit aperture **134** and X-slit aperture **130** in the Z dimension in relation to donor **120**, thereby allowing Y-slit aperture **134** and X-slit aperture **130** to be used as a reference for setting up the best focus position of multichannel laser printhead **116** without the need for performing an actual printing operation. The assembly of X-slit aperture **130** and X-photodetector **138** and the assembly of Y-slit aperture **134** and Y-photodetector

140 provide a reliable reference for use when multichannel laser printhead **116** is replaced or calibrated, or when the health of multichannel laser printhead **116** is verified. The method outlined in method **600** allows for the aligning of the printhead in three degrees of freedom based upon the use of at least three sets of laser irradiance profiles from three different groups of at least one channel of the multichannel laser printhead. The final two degrees of freedom, X and Y are then established with respect to the X and Y coordinates of the motion control system.

FIG. 7 shows a flow diagram of a method **700** of initial setup of a printhead with the LT printer system within an LTT process for OLED fabrication in accordance with the invention. LT printer system **100** as described in FIGS. 1-5 is referenced throughout the steps of method **700**. The method **700** determines the offset distance between the material transfer plane and the narrow aperture plane and adjusting the position of the multichannel laser printhead in accordance with the offset distance.

Method **700** includes the following steps:

Step **710**: Installing donor and receiver into transfer chamber

In this step, a donor **120**, and an associated receiver (substrate) are installed within vacuum chamber **122** of LT station **112** of LT printer system **100**. Method **700** proceeds to step **712**.

Step **712**: Lowering Z height of multichannel laser printhead to –D position

In this step, from an estimated nominal best focus position N (see FIG. 2), the Z height of multichannel laser printhead **116** is lowered to a –D position that is, for example, -250 microns from N using a micrometer Z position translator, where N is determined analytically. Method **700** proceeds to step **714**.

Step **714**: Setting power level of laser to partially transfer organic material from a donor

In this step, the power level of the laser feeding multichannel laser printhead **116** is set such that, if multichannel laser printhead **116** is set at a best focus Z height, some, but not all, of the material from the donor **120** is transferred. This operation ensures that, when multichannel laser printhead **116** is at a Z height setting that is not at best focus, little or no material will be transferred to the substrate. Method **700** proceeds to step **716**.

Step **716**: Printing first swath

In this step, with the Z height position of multichannel laser printhead **116** set to –D, a first swath of printing occurs as multichannel laser printhead **116** translates in the fast scan direction (Y-axis) via motion control system **110** with all channels of the multichannel laser printhead **116** activated such that laser light beams **118** impinge upon donor **120**. The value of the Z height of multichannel laser printhead **116** associated with this swath is stored within the system controller **111** of LT printer system **100**. Method **700** proceeds to step **718.**

Step **718**: Raising Z height of multichannel laser printhead

In this step, the Z height of multichannel laser printhead **116** is raised by a predetermined increment ΔD using a micrometer Z position translator. ΔD is, for example, +25 microns. Method **700** proceeds to step **720**.

Step **720**: Printing next swath

In this step, multichannel laser printhead **116** is translated one step in the slow scan direction (X-axis) via motion control system **110**. A next swath of printing occurs adjacent to any previously printed swath via multichannel laser printhead **116** translating in the fast scan direction (Y-axis) via motion control system **110** with all channels of the multichannel laser printhead **116** activated such that laser light beams **118** impinge upon donor **120**. The value of the Z height of multichannel laser printhead **116** associated with this swath is stored within the system controller **111** of LT printer system **100**. Method **700** proceeds to step **722.**

Step **722**: Has +D position been reached?

In this decision step, it is determined whether the Z height of multichannel laser printhead **116** is set at the +D position. If no, method **700** returns to step **718**. If yes, method **700** proceeds to step **724**.

Step **724**: Removing donor and receiver sheets

In this step, donor **120** and the associated receiver (substrate) are removed from within vacuum chamber **122** of LT station **112** of LT printer system **100** and are transferred to an optical inspection station. Method **700** proceeds to step **726.**

Step **726**: Inspecting swaths on receiver sheet

In this step, the receiver (substrate) is visually inspected and the swath is located with the largest amount of material from the donor. Method **700** proceeds to step **728**.

Step **728**: Determining Z height of multichannel laser printhead for best focus position

In this step, the Z height of multichannel laser printhead **116** for the best focus position is determined to be at the Z height that corresponds with the swath located in step **726** (as retrieved from the controller **111** of LT printer system **100**) having the largest amount of transferred material. The corresponding correction values or amplitudes of adjustment to the height Z of multichannel laser printhead **116** are also determined. Method **700** proceeds to step **730**.

Step **730**: Setting Z height of multichannel laser printhead to best focus position

In this step, the Z height of multichannel laser printhead **116** is set at the Z height, based upon the correction values that corresponds with the position determined in step **728** that resulted in the largest amount of transferred material. Method **700** proceeds to step **732**.

Step **732**: Storing Z height of multichannel laser printhead for best focus position

In this step, the Z height of multichannel laser printhead **116** that corresponds with the position determined in step **728** and the offset distance, or difference in height between the material transfer plane of donor **120** and the narrow aperture plane, or Y-slit aperture **134** are stored in the controller **111** of LT printer system **100**. Method **700** ends.

In summary, method **700** is a method of determining the best focus setting of multichannel laser printhead **116** in relation to the material transfer plane of donor **120** for initial setup of a multichannel laser printhead within an LTT process for OLED fabrication in accordance with the invention. Method **700** is also used should a change in position ever occur between the material transfer plane of donor **120** and either Y-slit aperture **134** or X-slit aperture **130**.

FIG. 8 shows a flow diagram of a method **800** of measuring the irradiance profiles of laser light beams and measuring the total power of a printhead within an LT process for OLED fabrication in accordance with the

invention. It is assumed that methods **600** and **700** have been performed prior to the start of method **800** and the multichannel laser printhead is focused to the X-slit and Y-slit aperture plane. LT printer system **100,** as described in FIGS. 1-5, is referenced throughout the steps of method **800**. When all channels are activated on, they need to provide sufficient laser irradiance and uniformity to transfer most or all of the donor material to the receiver in the LT station **112,** e.g. be sufficiently above a transfer threshold. When all channels are activated off, they need to be sufficiently low in irradiance, and high in contrast and uniformity, so as to transfer little or no donor material to the receiver in the LT station **112,** e.g. be sufficiently below transfer threshold.

Method **800** includes the following steps:

Step **810**: Setting first polarity state of multichannel laser printhead modulator

In this step, the first of two polarity states, for example voltage polarity, of the laser printhead modulator is set. Method **800** proceeds to step **812**.

Step **812**: Positioning multichannel laser printhead to X-slit aperture

In this step, multichannel laser printhead **116** is translated along the X-axis and Y-axis of LT printer system **100** using motion control system **110** such that multichannel laser printhead **116** is located in alignment with X-slit aperture **130**. Method **800** proceeds to step **814**.

Step **814**: Scanning multichannel laser printhead across X-slit aperture and measuring laser irradiance profile

In this step, all channels of multichannel laser printhead **116** are in an activated on condition and multichannel laser printhead **116** is scanned across X-slit aperture **130** along the X-axis using motion control system **110**. The resulting laser light beams **118** sequentially pass through slit **132** of X-slit aperture **130** and impinge upon X-photodetector **138**. X-photodetector **138** detects the irradiance of laser light beams **118** and accordingly generates an output signal that is received and recorded by the controller **111** of LT printer system **100**. The output signal of X-photodetector **138** is gathered as a function of the X position of multichannel laser printhead **116**, as received from the motion control system **110**, and as shown, for example, by ON curve **510** in plot **500** of FIG. 5. Method **800** proceeds to step **816**.

Step **816**: Irradiance values within tolerance?

In this decision step, the irradiance values of laser light beams **118**, which range from $I_{ON}max$ to $I_{ON}min$ as shown in FIG. 5, are verified to be within a predetermined limit, for example, $\leq 15\%$ of $I_{ON}max$. If the values are within tolerance, method **800** proceeds to step **824**. If not, method **800** proceeds to step **817**.

Step **817**: Multichannel laser printhead failure?

In this decision step, it is determined whether there is a gross failure of multichannel laser printhead **116** based upon the laser light beams irradiance values measured in step **814**. If so, or if it is determined that multichannel laser printhead **116** requires a channel balancing operation numerous times (e.g., more than four times), method **800** proceeds to step **818**. If not, method **800** proceeds to step **820**.

Step **818**:Take Corrective Action?

In this decision step, it is determined whether the multichannel laser printhead **116** should be closely monitored, replaced, or repaired.

Step **820**: Channel balance

In this decision step, it is determined whether multichannel laser printhead **116** requires a channel balance procedure based upon the laser irradiance values measured in step **814**. If yes, method **800** proceeds to step **822**; if no, method **800** proceeds to step **824**.

Step **822**: Performing channel balance

In this step, the irradiance level of each laser light beam channel (or each group of two or more laser light beams, as in EP 1 094 925) is adjusted to have similar irradiance values. Alternately, the pulse width of each light beam channel during writing is adjusted so that a similar energy is delivered to the material of donor **120**, taking into account any reciprocity failure. Method **800** then returns to step **812**.

Step **824**: Determining contrast

In this step, all channels of multichannel laser printhead **116** are deactivated (I_{off}), or in the activated off condition, and multichannel laser printhead **116** is scanned across X-slit aperture **130** along the X-axis using motion

control system **110**. The remaining laser light beam channel emission passes through slit **132** of X-slit aperture **130**, and X-photodetector **138** detects any channel emission and accordingly generates an output signal that is received and recorded by the controller **111** of LT printer system **100**. The output signal of X-photodetector **138** is gathered as a function of the X position of multichannel laser printhead **116**, as received from the motion control system **110**, and as shown, for example, by OFF curve **520** in plot **500** of FIG. 5. The ratio of I_{ON}/I_{OFF} is calculated for each channel of multichannel laser printhead **116** and is recorded by the controller **111** of LT printer system **100**. Method **800** proceeds to step **826**.

Step **826**: Contrast failures?

In this decision step, the calculated ratio of I_{ON}/I_{OFF} for each channel of multichannel laser printhead **116** is compared to a predetermined acceptable value, such as $\geq$10, to determine whether the contrast of any channel has failed. Any channel of multichannel laser printhead **116** whose calculated ratio of I_{ON}/I_{OFF} exceeds this predetermined acceptable value is classified as a contrast failure. If a channel is found to have failed, method **800** proceeds to step **828**. If no channel has failed, method **800** proceeds to step **830**.

Step **828**: Identifying bad channel

In this step, the failed channel is identified based upon the X position of multichannel laser printhead **116** that correlates with the failing I_{ON}/I_{OFF} value. Method **800** proceeds to step **818**.

Step **830**: Setting laser current

In this step, the relationship between laser drive current and total printhead output power is determined using the sum of the I_{ON} values of all channels of multichannel laser printhead **116** as measured in step **814** and the currently detected laser drive current from the controller **111**. This sum is an indicator of total printhead output laser power when the curve is integrated. Method **800** proceeds to step **832**.

Step **832**: Both polarity states of modulator measured?

In this decision step, it is determined whether the channel irradiance profiles have been measured for both polarity states of the modulator. If yes, method **800** ends; if no, method **800** proceeds to step **834**.

Step **834**: Reversing polarity state of modulator

In this step, the second of the two polarity states is set. Method **800** returns to **812**.

In summary, LT printer system **100**, which includes LT station **112** and detection system **114** mounted upon motion control system **110**, provides a system for and method of aligning, calibrating, and maintaining (i.e., methods **600**, **700**, and **800**, respectively) a multichannel laser printhead, such as multichannel laser printhead **116**, in an LTT process for manufacturing OLED display devices, thereby minimizing errors in processing, achieving uniform printing, and providing a simple detection method of evaluating or verifying the health of a multichannel laser printhead in an LTT process for manufacturing OLED display devices.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

100	laser thermal (LT) printer system
110	motion control system
111	controller
112	LT station
113	positional commands
114	detection system
115	printhead control commands
116	multichannel laser printhead
117	irradiance data
118	laser light beams
119	positional data
120	donor
122	vacuum chamber
124	window
126	chamber wall
128	window
130	X-slit aperture
132	slit
134	Y-slit aperture
135	X-attenuator
136	slit
137	Y-attenuator
138	X-photodetector
140	Y-photodetector
142	enclosure
144	CCD camera
200	exploded view
300	plot
310	curve

PARTS LIST (con't)

320	curve
330	curve
400	exploded view
500	plot
510	ON curve
520	OFF curve
600	method of replacing multichannel laser printhead
610	block
612	block
614	block
616	block
618	block
620	block
622	block
624	block
626	block
628	block
630	block
632	block
634	block
636	block
638	block
640	block
642	block
644	block.
700	method of initial setup of a printhead
710	block
712	block
714	block

PARTS LIST (con't)

716	block
718	block
720	block
722	block
724	block
726	block
728	block
730	block
732	block
800	method of measuring the irradiance profiles of laser light beams
810	block
812	block
814	block
816	block
817	block
818	block
820	block
822	block
824	block
826	block
828	block
830	block
832	block
834	block